



RESEARCH ARTICLE

# Characterization of particulate organic matter in soils of selected districts in agro-climatic zones of Tamil Nadu, India

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## Abstract

Cropping practices and agro-climatic conditions at specific sites have a direct impact on the processes involved in organic matter accumulation in cultivated soils. Soil particulate organic matter (POM) contributes significantly to soil fertility by improving nutrient status and availability. A study on delineation of soils in selected districts of Tamil Nadu was carried out by collecting surface soil samples from continuously cropped lands. Surface soil samples were taken at 15 cm depth from 37 villages across 16 major districts representing the 7 agro-climatic zones of Tamil Nadu. A series of tests were carried out to record POM parameters linked to soil fertility in continuous cropping. POM levels were found high ( $> 5 \text{ g kg}^{-1}$ ) in 16 locations, with the majority of those in the hilly, high-altitude, high-rainfall and Cauvery delta zones. In the western zone, the soils from the long-term fertilizer experiment (LTFE) and the permanent manurial experiment (PME) also had high POM concentrations. Within the total POM component, coarse POM (0.5 - 2.0 mm) constituted to 94.5 %, fine POM ( $< 0.5 \text{ mm}$  - floating) constituted to 77.2 % and bound POM ( $< 0.5 \text{ mm}$  - particle bound) constituted to 60.0 % in soils. In correlation analysis, POM exhibited a strong negative relationship with soil pH and  $\text{CaCO}_3$  whereas a strong positive relationship with SOC.

**Keywords:** agro-climatic zones; long-term fertilizer experiment; permanent manurial experiment; soil organic carbon; soil particulate organic matter

## Introduction

Soil organic matter (SOM) is the organic fraction of soil derived from plant and animal residues at various stages of decomposition. It is the material that remains in soil in the balance between carbon dioxide ( $\text{CO}_2$ ) fixation by plants during photosynthesis and release of carbon dioxide by microbial respiration during decomposition. Cropping practices and agro-climatic conditions of a specified location have direct control to the processes involved in organic matter accumulation in cultivated soils. Continuous cropping systems in which the soil is frequently tilled carbon cycling and result in exhaustion of organic matter reserves of soil. Loss of organic matter reserves leads to loss in soil fertility. Conservation of soil fertility in continuously cropped lands therefore requires regular addition of organic materials in soil. Alternatively, allowing land to lie fallow may gradually restore soil organic matter.

Organic matter in soil consists of a major part of plant residues and added manures at various stage of decomposition that are light brown to brown in colour and a minor part of unidentifiable highly humified material that are dark brown to black in colour. Physically, the organic materials in soil below 2 mm size is referred to as SOM and fraction representing large pieces of plant debris within the size fraction of 0.053–2 mm is referred as POM. Abundance of POM in soil depends on the quantity and quality of crop residues, soil

management history and soil texture (1). In tropical regions, the distribution of POM and SOM in most of the soils is found nearly in equal proportion (2).

Under continuous arable cropping systems, once soil organic carbon equilibrium levels reached stabilized then modern farming systems may not cause further decline in soil organic carbon easily (3). Accumulation rate of organic matter in soil is dominantly influenced by annual rainfall, land use pattern, cropping frequency and type of tillage (4). In soils under permanent vegetation, where large quantities of litter accumulate, POM tends to build up in high proportions (5, 6). Under humid conditions retention of soil carbon is stabilized on mineral surfaces and result in soil acidification which further reduce decomposition of SOM (7, 8). In spite of sufficient availability of water, prevalence of cold temperature limits microbial activity in soil to a greater degree (9).

As a result of influence of climate and topography, POM content in soils usually increase under cool humid conditions and decrease under warm drier climates (10, 11). Crop rotation enhances POM accumulation compared to monoculture (12). Cultivation of perennial crops, forages and cover crops noticeably raise up POM content of soils (13). In arid or semi-arid situations, lack of water availability limits POM accumulation (14).

Globally, POM can account for 20 - 40 % of total soil organic carbon, depending on land use and climate conditions (15). In India, long-term field experiments have shown that continuous application of organic amendments such as vermicompost and crop residues significantly increases POM- C and improves SOM quality indicators (16). However, intensive cultivation has led to decline in native soil organic carbon in many Indian agricultural soils (17, 18).

India's vast geographical diversity has led to the classification of the country into 15 agro-climatic zones based on physiography, soil types, rainfall, temperature, water resources and cropping patterns (19), while Tamil Nadu is divided into 7 agro-climatic zones, each with distinct soil types, rainfall patterns and cropping systems (20). Each zone exhibits distinct soil and climatic characteristics that influence organic matter dynamics.

Contribution of nutrients from POM and SOM are prodigious in a manner that the most activities physical, chemical and biological fertility of soils are related to them. Therefore, it is imperative to assess the distribution of POM in soils and its relationship with soil properties to enhance crop cultivation. With this background, the present study aims to characterize the distribution of POM in soils from selected districts across 7 agro-climatic zones of Tamil Nadu, representing a range of climatic and edaphic conditions. By comparing POM and SOM levels and their relationships with soil properties, this research seeks to identify zone-specific patterns for sustainable soil fertility management strategies.

## Materials and Methods

### Soil sample collection

Tamil Nadu consists of 38 districts and represents 7 agro-climatic zones viz., North-western zone, North-eastern zone, Western zone, Cauvery delta zone, Southern zone, high rainfall Zone and Hilly Zone. To study the influence of agro-climate, soil type and cropping pattern on the formation of POM in soils, delineated the representative areas in Tamil Nadu and surface soil samples were collected. At the site of collection surface debris were removed and soil sample was dug out up to 0 -15 cm depth using hand sampling tool/spade in 5 spots within 20 m spread. The samples were composited on a polythene sheet, mixed thoroughly using the quartering method and about 2 kg of soil was collected in a cloth bag and labelled. The latitude and longitude of each sampling location were recorded using the cellular Google Maps application (Table 1), with coordinates ranging from 8.3616° N to 12.6691° N latitude and 76.6154° E to 79.6808° E longitude, encompassing diverse agro-climatic zones across Tamil Nadu (Table 2).

Covering all agro-climatic zones 37 soil samples were collected (Fig. 1 and Fig. 2). Samples were collected in 16 districts viz., Tiruvannamalai, Vellore, Kanchipuram, Salem, Krishnagiri, Dharmapuri, Erode, Coimbatore, Karur, Ariyalur, Thanjavur,

Virudhunagar, Madurai, Thothukudi, Kanyakumari and Udhamandalam. Among soil samples collected from Coimbatore district, 2 soil samples represent permanent manurial experiments which are in progress in Tamil Nadu Agricultural University (TNAU), Coimbatore campus.

### Characterization of soils for basic physical and chemical properties

The processed soil samples were analyzed following standard procedures: pH by potentiometry (21), electrical conductivity by conductometry (21), cation exchange capacity by neutral normal NH<sub>4</sub>OAc (22) and free CaCO<sub>3</sub> by rapid titration (23). Soil pH and electrical conductivity were estimated in 1:2.5 soil-water suspension. Particle size group analysis was carried out for the interpretation of soil texture by international pipette method (23).

### Characterization of soil organic matter constituents

Soil samples were analyzed for soil organic carbon (SOC) and POM. Using a dry sieving method, POM was fractionated into three groups: coarse POM, fine POM and bound POM. By floatation method initially coarse POM and fine POM fractions were separated. Bound POM considered to be adhering to soil particles was calculated by difference.

### Separation and quantification of particulate organic matter

The size fraction of POM in soil is ranging from 0.053 mm to 2.0 mm. This fraction can be isolated by dispersing soil using 0.5 % sodium hexa meta phosphate (SHMP) solution (24).

For POM separation 10 g of processed soil were taken in 100 mL wide mouth polythene shaking container, then 30 mL of 0.5 % sodium hexa meta phosphate solution was added and shaken in a mechanical shaking machine for 18 hr. The role of SHMP is to break soil aggregates and disperse off bound organic particles. After shaking, the supernatant contents were washed with 1 L distilled water in 15 or more instalments. The washed suspension was passed 0.053 mm sieve and the organic matter retained was transferred to a pre-weighed aluminium pan and dried in oven at 70 °C until a constant weight. This organic material was weighed and referred as POM (0.053-2.0 mm) (Fig. 3).

### Separation and quantification of fractions of POM

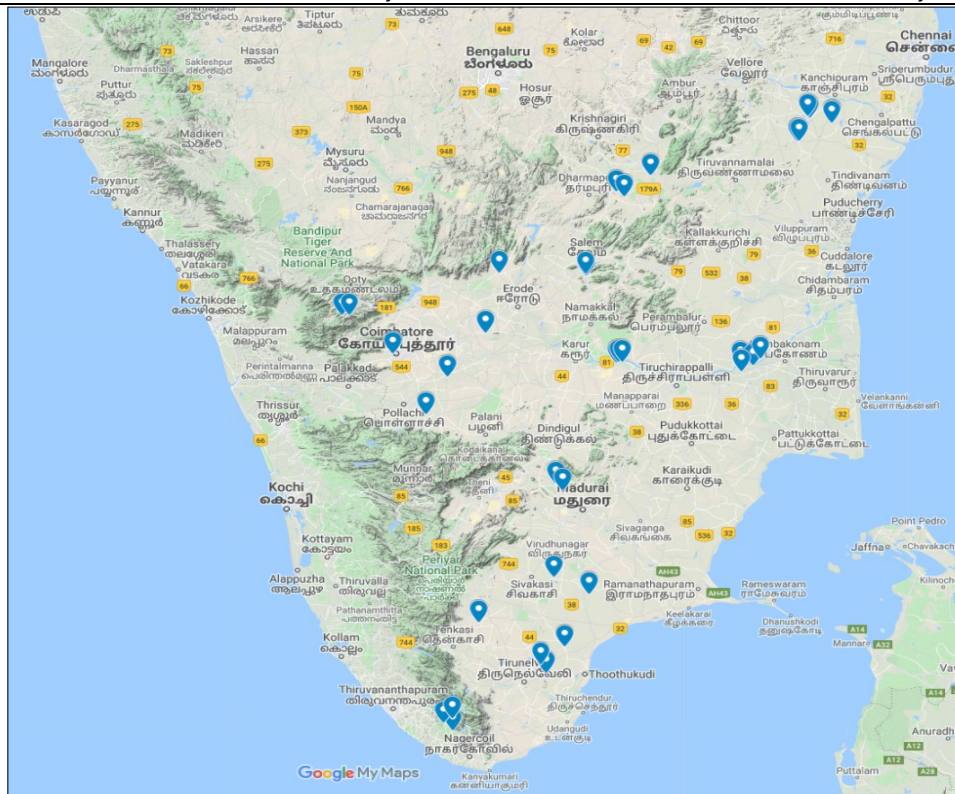
Within POM, the physical fractions of various size groups were fractionated without using dispersing agent. These size groups are coarse POM (0.5-2.0 mm), fine POM (< 0.5 mm - floating) and bound POM (< 0.5mm - particle bound). Coarse and fine POM fractions were quantified by physical dry sieving method. Bound POM was determined by difference, subtracting the sum of coarse and fine POM from the total POM. These steps were formulated to find out a quick method for identifying the major fraction of POM that can render physical and nutritive impact in soils (25).

**Table 1.** District-wise distribution of soil samples across agro-climatic zones of Tamil Nadu

Agro-climatic zone	District	No. of samples	Agro-climatic zone	District	No. of samples
North-eastern zone	Tiruvannamalai	2	Cauvery Delta zone	Karur	3
	Vellore	2		Ariyalur	1
	Kanchipuram	2		Thanjavur	3
Salem	2	Virudhunagar		2	
North-western zone	Krishnagiri	1	Southern zone	Madurai	2
	Dharmapuri	2		Thothukudi	4
	Erode	2	High rainfall zone	Kanyakumari	3
Western zone	Coimbatore	4		Udagamandalam	2
Total soil samples collected			Hilly zone		37

**Table 2.** Location details of soil sample collection in districts of Tamil Nadu

Soil sample No.	Agro climatic zone	District	Location of soil sample collection	Latitude	Longitude	Predominant crop	
S <sub>1</sub>	NEZ	Tiruvannamalai	Cheyyar	12.657741	79.553478	Sugarcane	
S <sub>2</sub>	NEZ	Tiruvannamalai	Vadathandalam	12.669149	79.524733	Maize	
S <sub>3</sub>	NEZ	Vellore	Mazhaiyur	12.497431	79.457143	Sugarcane	
S <sub>4</sub>	NEZ	Vellore	Aliyur	12.497209	79.471952	Sugarcane	
S <sub>5</sub>	NEZ	Kanchipuram	Manampathi	12.629539	79.680837	Groundnut	
S <sub>6</sub>	NEZ	Kanchipuram	Kandigai	12.618834	79.671873	Sugarcane	
S <sub>7</sub>	NWZ	Salem	Mallur	11.556567	78.138821	Onion	
S <sub>8</sub>	NWZ	Salem	Pasuvanathampatty	11.573127	78.134052	Brinjal	
S <sub>9</sub>	NWZ	Krishnagiri	Uthangakarai	12.254868	78.541345	Lablab	
S <sub>10</sub>	NWZ	Dharmapuri	Mukanurpatti G	12.142916	78.326142	Brinjal	
S <sub>11</sub>	NWZ	Dharmapuri	Morappur	12.109794	78.377862	Bottle gourd	
S <sub>12</sub>	WZ	Erode	Anthiyur	11.575485	77.598135	Maize	
S <sub>13</sub>	WZ	Erode	Kuthampalayam	11.154231	77.506686	Maize	
S <sub>14</sub>	WZ	Coimbatore	Sinjuvadi	10.588072	77.133965	Maize	
S <sub>15</sub>	WZ	Coimbatore	Jallipatti	10.850631	77.272789	Maize	
S <sub>16</sub>	WZ	Coimbatore	TNAU- LTFE	11.016149	76.936012	Maize	
S <sub>17</sub>	WZ	Coimbatore	TNAU- PME	11.009781	76.933307	Maize	
S <sub>18</sub>	CDZ	Karur	Chinthalavadi	10.947511	78.325117	Rice	
S <sub>19</sub>	CDZ	Karur	Lalapettai	10.952873	78.337927	Rice	
S <sub>20</sub>	CDZ	Karur	Karuppathur	10.950645	78.363096	Rice	
S <sub>21</sub>	CDZ	Ariyalur	Thirumanur	10.939322	79.100246	Rice	
S <sub>22</sub>	CDZ	Thanjavur	Pattukudi	10.929611	79.183131	Rice	
S <sub>23</sub>	CDZ	Thanjavur	Thiruvaiyaru	10.888873	79.107446	Rice	
S <sub>24</sub>	CDZ	Thanjavur	Kuruvasi	10.981043	79.228202	Rice	
S <sub>25</sub>	SZ	Virudhunagar	Tulukkappatti	9.444859	77.939318	Greengram	
S <sub>26</sub>	SZ	Virudhunagar	Avudaiyapuram	9.129077	77.466379	Blackgram	
S <sub>27</sub>	SZ	Madurai	Vadipatti	10.105206	77.946656	Blackgram	
S <sub>28</sub>	SZ	Madurai	Andipatti	10.057607	77.992884	Greengram	
S <sub>29</sub>	SZ	Thothukudi	Venkateswarapuram	8.955784	78.003367	Blackgram	
S <sub>30</sub>	SZ	Thothukudi	Kasilingapuram	8.772865	77.888969	Greengram	
S <sub>31</sub>	SZ	Thothukudi	Lakshmiapuram	8.828537	77.856534	Blackgram	
S <sub>32</sub>	SZ	Thothukudi	Sennampatti	9.321784	78.159169	Blackgram	
S <sub>33</sub>	HRZ	Kanyakumari	Kulasekharam	8.361604	77.303186	Rubber	
S <sub>34</sub>	HRZ	Kanyakumari	Mancode	8.418549	77.242678	Rubber	
S <sub>35</sub>	HRZ	Kanyakumari	Pechiparai	8.452596	77.298981	Rubber	
S <sub>36</sub>	HZ	Udhagamandalam	Mulligoor	11.279861	76.615447	Tea	
S <sub>37</sub>	HZ	Udhagamandalam	Manjoor	11.282234	76.655181	Tea	
NEZ	North-Eastern Zone	WZ	Western zone	SZ	Southern Zone	HRZ	High rainfall Zone
NWZ	North-Western Zone	CDZ	Cauvery Delta Zone			HZ	Hilly and high altitude zone

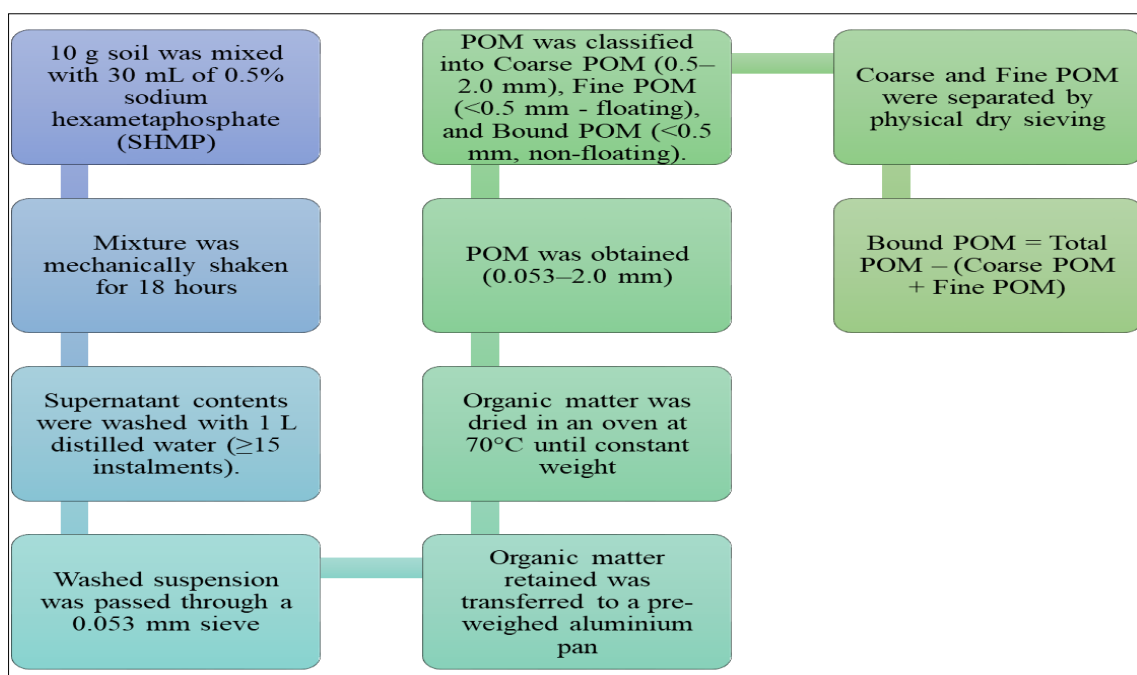


Districts covered for sampling in Agro-Climatic zones

**Fig. 1.** Map of Tamil Nadu showing the sampled locations of soil collection across 7 agro-climatic zones. The base map was generated using Google Maps and annotated to indicate district-wise sampling points.



**Fig. 2.** Representative vegetation and cropping patterns observed at soil sampling locations across villages in Tamil Nadu: a) Tiruvannamalai – Cheyyar b) Salem – Mallur c) Krishnagiri – Uthangakarai d) Dharmapuri - Mukanurpatti G e) Erode – Anthiyur f) Coimbatore-Jallipatti g) Karur – Lalapettai h) Karur- Chinthalavadi i) Ariyalur - Thirumanur j) Thothukudi – Sennampatti k) Kanyakumari – Kulasekharam l) Udagamandalam – Mulligoor.



**Fig. 3.** Flowchart for soil POM fractionation (24).

In the process, 150 g soil (2-mm sieved) was weighed and placed on top of 0.5 mm sieve inside a container filled with 1 L of distilled water and immersed into water for 5 min before sieving. Wet sieving was done by moving the sieve up and down for 10 min. After wet sieving, the materials on 0.5 mm sieve were collected along with sand and POM. From this material, POM fraction was isolated by floatation in water and the coarse sand was removed in further steps.

POM was fractionated into coarse (> 0.5 mm) and fine (< 0.5 mm) components using wet sieving followed by floatation. In both cases, the material retained after sieving was transferred to a 1 L measuring cylinder, soaked in 500 mL of distilled water for 30 min to allow slaking and dispersion and subjected to short periods of shaking to bring lighter organic particles to the surface. Floating material was carefully decanted onto a pre-weighed nylon cloth placed over a beaker, with repeated rinsing of the cylinder walls until the suspension was clear. The retained POM fractions were oven-dried at 70°C to constant weight and their mass determined by subtracting the initial cloth weight from the final cloth + POM weight (Fig. 4).

The bound POM fraction (< 0.5 mm – non-floating) was identified as POM fraction that was strongly adhered to fine soil particles (clay + silt) and has not floated as dispersion agent was not added. This bound fraction was accounted for by difference, by subtracting the weight of coarse POM+ fine POM from the whole POM estimated.

#### Correlation analysis between properties of soil and particulate organic matter

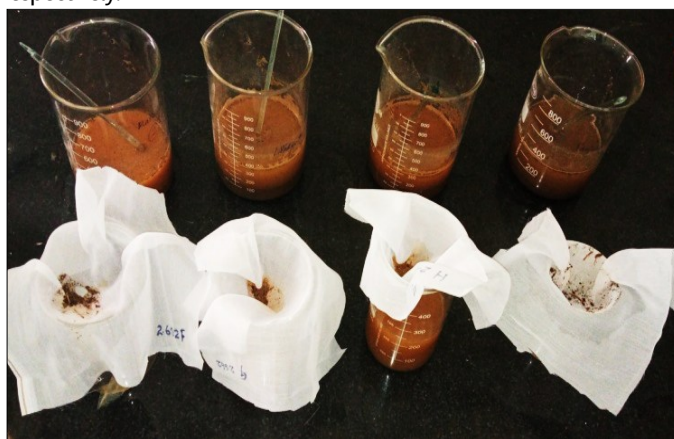
##### Statistical analysis

Simple correlation analysis was performed for the estimated independent soil properties including soil reaction, electrical conductivity, cation exchange capacity, soil particle size groups and calcium carbonate content. These were analyzed in relation to the dependent properties namely, the status of whole and fractional POM (26).

## Results and discussion

### Physical and chemical properties of soils

The general information on altitude, annual rainfall and crops grown commonly in each agro-climatic zone has been reported by Tamil Nadu government (20). The soil texture, soil colour and basic chemical properties of the soils collected are given in Table 3, 4 and 5 respectively.



**Fig. 4.** POM fraction isolation by floatation in water.

The study locations in the north-eastern (S<sub>1</sub>-S<sub>6</sub>) and north-western (S<sub>7</sub>-S<sub>11</sub>) agro-climatic zones differ mainly in elevation and rainfall. The north-eastern zone lies at an altitude of approximately 100-200 m above mean sea level (MSL) and receives an average annual rainfall of about 1105 mm, whereas the north-western zone is situated at 200-600 m MSL and receives around 875 mm annually (27).

Soil reaction in these zones ranges from neutral to slightly calcareous (pH < 8.2), with low soluble salt concentrations (<1 dS m<sup>-1</sup>). The moderate rainfall (875-1105 mm) contributes to the formation of low-level lateritic soils. These soils are likely dominated by silicate clays that has been reflected by cation exchange capacity (CEC) values exceeding 8 cmol (p<sup>+</sup>) kg<sup>-1</sup> in most locations. The presence of calcium carbonate (CaCO<sub>3</sub>) greater than 6 % in several areas may have enhanced base saturation at clay exchange sites, thereby increasing soil pH from neutral to 8.0. The predominant soil color in these agro-climatic zones is yellowish brown to brown, with smaller occurrences of reddish brown and gray soils. Major crops grown are sugarcane, groundnut, maize and vegetables.

The western agro-climatic zone (S<sub>12</sub>-S<sub>17</sub>), located at an elevation ranging between 200 and 600 m MSL, receives moderate annual rainfall of approximately 715 mm. Due to relatively low rainfall, pedogenic processes may be slower, resulting in soil reactions tending toward calcareousness (pH > 8.2), with CaCO<sub>3</sub> content approaching 9 %. The slow rate of soil weathering likely favors the dominance of 2:1 silicate clays, contributing to CEC values exceeding 10 cmol (p<sup>+</sup>) kg<sup>-1</sup> in many locations. The predominant soil color in this zone is brown to reddish brown, with some pockets of dark gray/black soils. Common crops in this zone include maize, sorghum, minor millets and pulses (27).

The Cauvery delta zone (S<sub>18</sub>-S<sub>24</sub>) lies in an alluvial plain at an elevation of 100-200 m MSL and receives moderately high annual rainfall of about 984 mm. The majority of lands are supported by canal irrigation. Rice is the predominant crop. Prolonged soil submergence leads to a well-buffered soil reaction near neutral (pH ~7.5). Continuous river irrigation and rainfall result in low salt accumulation (EC < 1 dS m<sup>-1</sup>). CaCO<sub>3</sub> content is generally below 6 %. The accumulation of water-transported silicate clays may explain the CEC range of 3-11 cmol (p<sup>+</sup>) kg<sup>-1</sup>. The predominant soil color in this zone is brown to dark brown, with some pockets of reddish brown. In addition to rice, rice-fallow pulses, maize and millets are also cultivated (27).



**Table 3.** Soil texture of soil samples collected

Soil sample No.	Name of sampled location	Soil separates (%)				Soil texture
		Coarse sand	Fine sand	Silt	Clay	
S <sub>1</sub>	Cheyyar	45.74	29.51	3.75	20.75	scl
S <sub>2</sub>	Vadathandalam	36.10	26.00	7.21	30.09	scl
S <sub>3</sub>	Mazhaiyur	51.16	16.79	12.14	19.81	sl
S <sub>4</sub>	Aliyur	35.54	28.01	5.21	31.14	scl
S <sub>5</sub>	Manampathi	40.41	30.48	6.37	22.49	scl
S <sub>6</sub>	Manampathi Kandigai	38.76	21.11	9.27	30.57	scl
S <sub>7</sub>	Mallur	43.02	34.08	2.30	19.93	sl
S <sub>8</sub>	Pasuvanathampatty	53.93	26.69	4.87	13.81	sl
S <sub>9</sub>	Uthangakarai	35.06	18.57	11.29	34.53	scl
S <sub>10</sub>	Mukanurpatti G	30.44	16.76	10.15	41.80	scl
S <sub>11</sub>	Morappur	41.89	20.41	16.67	20.93	scl
S <sub>12</sub>	Anthiyur	38.48	12.42	14.30	34.04	scl
S <sub>13</sub>	Kuthampalayam	40.07	23.82	12.98	22.84	scl
S <sub>14</sub>	Sinjuvadi	17.89	7.41	18.68	55.22	c
S <sub>15</sub>	Jallipatti	55.19	32.16	2.56	9.63	ls
S <sub>16</sub>	TNAU-LTFE	33.50	14.25	20.77	25.48	sl
S <sub>17</sub>	TNAU-PME	44.82	20.28	15.20	19.08	sl
S <sub>18</sub>	Chinthlavadi	35.80	19.87	8.98	34.69	scl
S <sub>19</sub>	Lalappettai	36.32	28.06	10.59	24.69	scl
S <sub>20</sub>	Karuppathur	38.25	23.62	13.17	24.66	scl
S <sub>21</sub>	Thirumanur	28.70	9.60	11.85	48.95	c
S <sub>22</sub>	Pattukudi	48.91	27.64	9.08	14.17	sl
S <sub>23</sub>	Thiruvaiyaru	49.11	22.57	11.35	16.89	sl
S <sub>24</sub>	Kuruvadi	57.24	22.03	13.67	6.87	ls
S <sub>25</sub>	Tulukkapatti	25.94	21.26	5.42	47.28	scl
S <sub>26</sub>	Avudaiyapuram	25.11	19.19	9.31	45.99	c
S <sub>27</sub>	Vadipatti	57.49	27.36	2.33	12.72	ls
S <sub>28</sub>	Andipatti	50.77	24.92	6.38	17.77	sl
S <sub>29</sub>	Venkateswarapuram	53.11	27.14	1.09	18.05	sl
S <sub>30</sub>	Kasilingapuram	64.45	24.55	1.54	9.16	ls
S <sub>31</sub>	Lakshmiapuram	38.74	26.41	11.74	22.31	scl
S <sub>32</sub>	Sennampatti	14.05	4.75	14.48	66.64	c
S <sub>33</sub>	Kulasekharam	43.27	21.33	15.26	20.04	scl
S <sub>34</sub>	Mancode	41.63	16.76	13.87	26.58	scl
S <sub>35</sub>	Pechiparai	33.81	18.58	18.96	28.36	scl
S <sub>36</sub>	Mulligoor	18.49	8.96	5.25	67.24	c
S <sub>37</sub>	Manjoor	19.87	9.78	13.62	56.34	c

**Table 4.** Soil colour under dry and wet conditions for soil samples collected

Soil sample No.	Munsell colour chart description			
	Dry soil colour		Wet soil colour	
	Notation	Name	Notation	Name
S <sub>1</sub>	2.5Y 4/1	Dark gray	2.5Y 3/1	Very dark gray
S <sub>2</sub>	2.5YR 5/2	Weak red	2.5YR 3/4	Dark reddish brown
S <sub>3</sub>	10YR 5/4	Yellowish brown	10YR 3/4	Dark yellowish brown
S <sub>4</sub>	7.5YR 5/3	Brown	7.5YR 4/2	Brown
S <sub>5</sub>	10YR 6/3	Pale brown	10YR 4/4	Dark yellowish brown
S <sub>6</sub>	10YR 5/4	Yellowish brown	10YR 3/4	Dark yellowish brown
S <sub>7</sub>	5YR 4/1	Dark gray	5YR 3/2	Dark reddish brown
S <sub>8</sub>	5YR 5/2	Reddish gray	5YR 2/2	Dark reddish brown
S <sub>9</sub>	10YR 5/4	Yellowish brown	10YR 4/2	Dark yellowish brown
S <sub>10</sub>	7.5YR 5/2	Brown	7.5YR 3/3	Dark brown
S <sub>11</sub>	7.5YR 4/4	Brown	7.5YR 3/4	Dark brown
S <sub>12</sub>	2.5YR 4/1	Dark gray	2.5YR 2.5/1	Black
S <sub>13</sub>	5YR 5/4	Reddish brown	5YR 3/2	Dark reddish brown
S <sub>14</sub>	2.5Y 4/2	Dark grayish brown	2.5Y 3/2	Very dark grayish brown
S <sub>15</sub>	7.5YR 5/2	Brown	7.5YR 3/2	Dark brown
S <sub>16</sub>	5YR 5/1	Gray	5YR 4/1	Dark gray
S <sub>17</sub>	5YR 4/3	Reddish brown	5YR 3/3	Dark reddish brown
S <sub>18</sub>	7.5YR 5/2	Brown	7.5YR 3/2	Dark brown
S <sub>19</sub>	7.5YR 5/2	Brown	7.5YR 3/3	Dark brown
S <sub>20</sub>	7.5YR 4/3	Brown	7.5YR 3/3	Dark brown
S <sub>21</sub>	7.5YR 5/1	Gray	7.5YR 2.5/1	Black
S <sub>22</sub>	2.5YR 6/3	Light reddish brown	2.5YR 4/2	Weak red
S <sub>23</sub>	2.5Y 4/2	Dark grayish brown	2.5Y 3/2	Very dark grayish brown
S <sub>24</sub>	2.5YR 5/2	Weak red	2.5YR 4/4	Reddish brown
S <sub>25</sub>	5YR 4/1	Dark gray	5YR 3/1	Very dark gray
S <sub>26</sub>	5YR 6/4	Light reddish brown	5YR 4/3	Reddish brown
S <sub>27</sub>	7.5YR 4/1	Brown	7.5YR 2.5/3	Very dark brown
S <sub>28</sub>	7.5YR 5/1	Gray	7.5YR 3/3	Dark brown
S <sub>29</sub>	2.5YR 4/6	Red	2.5YR 4/3	Reddish brown
S <sub>30</sub>	5YR 5/4	Reddish brown	5YR 4/4	Reddish brown
S <sub>31</sub>	2.5YR 5/3	Reddish brown	2.5YR 4/3	Reddish brown
S <sub>32</sub>	2.5YR 4/1	Dark reddish gray	2.5YR 2.5/1	Reddish black
S <sub>33</sub>	5YR 5/3	Reddish brown	5YR 3/2	Dark reddish brown
S <sub>34</sub>	5YR 4/4	Reddish brown	5YR 3/4	Dark reddish brown
S <sub>35</sub>	5YR 5/6	Yellowish red	5YR 4/6	Yellowish red
S <sub>36</sub>	5YR 4/2	Dark reddish gray	5YR 3/1	Very dark gray
S <sub>37</sub>	7.5YR 4/4	Brown	7.5YR 3/2	Dark brown

**Table 5.** Chemical characteristics of soils collected from various locations of Tamil Nadu

Soil Sample No.	Name of sampled location	pH	EC (dS m <sup>-1</sup> )	CEC cmol (p <sup>+</sup> ) kg <sup>-1</sup> soil	CaCO <sub>3</sub> (%)
S <sub>1</sub>	Cheyyar	7.39	0.05	9.40	7.69
S <sub>2</sub>	Vadathandalam	7.05	0.39	10.12	7.98
S <sub>3</sub>	Mazhaiyur	7.19	0.45	7.76	4.93
S <sub>4</sub>	Aliyur	6.33	0.42	10.53	1.23
S <sub>5</sub>	Manampathi	8.06	0.54	9.70	8.00
S <sub>6</sub>	Manampathi Kandigai	8.14	0.53	9.48	8.49
S <sub>7</sub>	Mallur	7.92	0.11	8.62	6.98
S <sub>8</sub>	Pasuvanathampatty	7.74	0.13	9.57	5.28
S <sub>9</sub>	Uthangakarai	7.88	0.05	7.40	6.97
S <sub>10</sub>	Mukanurpatti G	7.38	0.73	13.70	7.34
S <sub>11</sub>	Morappur	7.25	0.47	8.49	3.89
S <sub>12</sub>	Anthiyur	7.81	0.56	10.98	7.59
S <sub>13</sub>	Kuthampalayam	7.94	0.71	11.28	5.59
S <sub>14</sub>	Sinjuvadi	8.18	0.09	15.73	9.67
S <sub>15</sub>	Jallipatti	8.22	0.08	8.15	4.59
S <sub>16</sub>	TNAU-LTFE	8.48	0.15	13.68	9.64
S <sub>17</sub>	TNAU-PME	7.89	0.16	9.87	3.39
S <sub>18</sub>	Chinthlavadi	7.49	0.44	11.69	6.67
S <sub>19</sub>	Lalapettai	7.54	0.42	11.15	3.50
S <sub>20</sub>	Karuppathur	7.62	0.53	8.59	5.49
S <sub>21</sub>	Thirumanur	7.68	1.01	14.38	8.56
S <sub>22</sub>	Pattukudi	7.47	1.04	4.56	5.69
S <sub>23</sub>	Thiruvaiyaru	7.54	0.81	7.29	3.00
S <sub>24</sub>	Kuruvadi	7.39	1.02	3.89	3.48
S <sub>25</sub>	Tulukkapatti	8.12	0.09	19.90	9.56
S <sub>26</sub>	Avudaiyapuram	8.26	0.09	14.59	9.31
S <sub>27</sub>	Vadipatti	7.16	0.01	8.69	4.69
S <sub>28</sub>	Andipatti	6.84	0.01	5.80	1.49
S <sub>29</sub>	Venkateswarapuram	6.07	0.02	7.89	7.24
S <sub>30</sub>	Kasilingapuram	6.17	0.06	4.60	3.59
S <sub>31</sub>	Lakshmipuram	8.29	0.08	8.10	9.81
S <sub>32</sub>	Sennampatti	7.96	0.43	19.68	3.49
S <sub>33</sub>	Kulasekharam	4.58	0.26	6.97	0.70
S <sub>34</sub>	Mancode	4.65	0.25	8.89	0.44
S <sub>35</sub>	Pechiparai	5.94	0.24	8.75	0.16
S <sub>36</sub>	Mulligoor	4.64	0.14	14.98	0.46
S <sub>37</sub>	Manjoor	5.46	0.02	21.70	0.65
Minimum		4.58	0.01	3.89	0.16
Maximum		8.48	1.04	21.70	9.81

The southern zone (S<sub>25</sub> - S<sub>32</sub>) comprises plains and hillocks with elevations ranging from 100-600 m MSL and receives about 857 mm of rainfall annually. The parent material of the soils is predominantly derived from widespread granitic rocks. High temperatures and moderate rainfall result in non-saline soils (EC < 0.5 dS m<sup>-1</sup>), with soil pH ranging from 6 to 8 and CEC values between 4 and 20 cmol (p<sup>+</sup>) kg<sup>-1</sup>. These variations are likely influenced by the diverse topography. The predominant soil color in this zone is reddish brown, typical of well-drained soils. Pulses, oilseeds and fodder crops are commonly grown (28).

The high rainfall zone (S<sub>33</sub> - S<sub>35</sub>), located in Kanyakumari district, receives about 1420 mm of rainfall annually and features undulating terrain with elevations from 100 to 2000 m MSL. The tropical climate and persistent soil wetness promote the formation of lateritic soils. Soil reaction is acidic (pH < 6.5), likely due to low base

saturation, as reflected in minimal CaCO<sub>3</sub> content (< 1 %) and CEC values below 9 cmol (p<sup>+</sup>) kg<sup>-1</sup>. Rubber is a prominent agroforestry crop, while rice is widely grown in lowlands. Fruit trees such as jackfruit, mango and banana are cultivated in select areas and coconut is common in coastal regions (29).

Udagamandalam (S<sub>36</sub> - S<sub>37</sub>) belongs to the hilly and high-altitude agro-climatic zone, with elevations exceeding 2000 m MSL. The region receives very high annual rainfall (2124 mm), fostering dense vegetation on slopes and valleys. Cool temperatures promote the accumulation of organic matter and litter in soils. With negligible CaCO<sub>3</sub> content and active laterisation, acidic soils have developed (pH < 5.5), accompanied by high CEC values ranging from 14 to 22 cmol (p<sup>+</sup>) kg<sup>-1</sup>. Tea is the traditional plantation crop grown on slopes, while bench terraces and plains support potato, cabbage, cauliflower, other vegetables and ornamental crops (27).

### Particulate organic matter status of soils of Tamil Nadu

The distribution of SOM in soils was recorded by the estimation of SOC. From the estimated SOC content SOM content was derived. POM, the component of SOM was separately estimated as a distinct physical fraction. In soils of agro-climatic zones of Tamil Nadu the content of SOC was low ( $< 5 \text{ g kg}^{-1}$ ) in 10 locations, other 27 locations had high ( $> 5 \text{ g kg}^{-1}$ ) SOC. Particularly all soils under hilly zone ( $S_{36}$ -  $S_{37}$ ), high rainfall zone ( $S_{33}$ -  $S_{35}$ ) and Cauvery delta zone ( $S_{18}$ -  $S_{24}$ ), which are moist at most part of the year, recorded high SOC (Table 6). The very high account of SOC in hilly and high rainfall zones may be related to perennial vegetation rendering continuous addition of litter and crop residues on soil and cool climate restricting biological activity associated with organic matter decomposition.

In similar way, POM estimated in soils were high ( $> 5 \text{ g kg}^{-1}$ ) in hilly zone, followed by high rainfall zone and Cauvery delta zone. In rice-based cropping systems when fresh residues remain in soil, they become sites of microbial activity and then result in soil aggregation by binding of residues and soil particles into macroaggregates. Large sized POM fraction incorporated into macroaggregates subsequently decomposes and becomes fine POM. The C rich large fractions of POM dominated in paddy soil with long term use of fertilizers was recorded (30).

Soils of the renowned continuous cropping experiments ( $S_{16}$ -  $S_{17}$ ) of TNAU, Coimbatore viz., LTFE and PME also indicated high POM content in the western zone. Correspondingly the physical fractions estimated within POM were present in higher proportions in hilly, high rainfall and Cauvery delta zone as well as in continuous cropping experiments of western zone. Among the fractions of POM, the largest fraction was coarse POM, followed by smaller fractions of fine POM and bound POM.

In irrigated long-term experiments of TNAU, Coimbatore district maize followed by finger millet are raised in LTFE and maize followed by sunflower are raised in PME. For POM assessment soil samples were collected from high yielding plots under integrated nutrient management practice, where farmyard manure (FYM) was combined with 100 % recommended NPK. Every seasonal addition of FYM might have been responsible for the high fertility and high POM content recorded in these samples. In a similar study on LTFE in Coimbatore centre, highlighted the combined application of mineral fertilizers with FYM enhanced soil carbon stock and sequestration (31). This improvement was attributed to the accumulation of more recalcitrant forms of soil organic matter, higher cation exchange capacity and sustained nutrient availability in smectitic clay soils under continuous cropping. Continuous application organic manure along with inorganic fertilizers

**Table 6.** Soil organic carbon (SOC) and particulate organic matter status (POM)

Soil sample No.	Name of sampled location	SOC ( $\text{g kg}^{-1}$ )	POM ( $\text{g kg}^{-1}$ )	Fractions of POM ( $\text{g kg}^{-1}$ )		
				Bound POM	Fine POM	Coarse POM
		$<0.5$	$<2.0$	$<0.5$	$<0.5$	$0.5 - 2.0$
S <sub>1</sub>	Cheyyar	5.89	2.66	0.15	0.13	2.38
S <sub>2</sub>	Vadathandalam	7.49	6.28	0.14	1.56	4.58
S <sub>3</sub>	Mazhaiyur	5.59	5.98	0.10	2.17	3.71
S <sub>4</sub>	Aliyur	5.56	4.93	0.79	2.34	1.80
S <sub>5</sub>	Manampathi	2.89	2.31	0.12	0.21	1.98
S <sub>6</sub>	Manampathi Kandigai	4.46	0.59	0.04	0.06	0.49
S <sub>7</sub>	Mallur	5.84	3.15	0.08	0.91	2.16
S <sub>8</sub>	Pasuvanathampatty	3.90	0.59	0.03	0.01	0.55
S <sub>9</sub>	Uthangakarai	5.43	2.18	0.05	0.45	1.68
S <sub>10</sub>	Mukanurpatti G	5.85	2.71	0.56	0.78	1.38
S <sub>11</sub>	Morappur	4.73	6.28	0.12	1.87	4.29
S <sub>12</sub>	Anthiyur	6.12	3.47	0.04	0.15	3.28
S <sub>13</sub>	Kuthampalayam	4.73	0.51	0.17	0.19	0.22
S <sub>14</sub>	Sinjuvadi	9.17	0.60	0.06	0.42	0.12
S <sub>15</sub>	Jallipatti	1.67	1.05	0.63	0.16	0.26
S <sub>16</sub>	TNAU-LTFE	6.40	8.36	0.43	2.94	4.99
S <sub>17</sub>	TNAU-PME	6.12	7.30	2.02	3.32	1.96
S <sub>18</sub>	Chinthalavadi	6.49	4.54	0.73	1.89	1.92
S <sub>19</sub>	Lalapettai	7.32	5.12	0.19	0.74	4.19
S <sub>20</sub>	Karuppathur	5.27	5.10	0.44	2.03	2.63
S <sub>21</sub>	Thirumanur	9.07	4.43	0.13	0.34	3.96
S <sub>22</sub>	Pattukudi	5.46	6.66	1.60	1.01	4.05
S <sub>23</sub>	Thiruvaiyaru	5.81	6.97	1.71	2.54	2.72
S <sub>24</sub>	Kuruvadi	6.37	5.92	0.24	3.89	1.79
S <sub>25</sub>	Tulukkapatti	7.15	2.30	0.14	0.29	1.87
S <sub>26</sub>	Avudaiyapuram	5.37	2.18	0.09	1.34	0.75
S <sub>27</sub>	Vadipatti	5.79	7.43	0.37	3.13	3.93
S <sub>28</sub>	Andipatti	2.46	0.46	0.06	0.12	0.28
S <sub>29</sub>	Venkateswarapuram	3.22	0.48	0.05	0.15	0.28
S <sub>30</sub>	Kasilingapuram	6.12	1.67	0.11	1.28	0.28
S <sub>31</sub>	Lakshmipuram	2.23	2.28	0.20	1.76	0.32
S <sub>32</sub>	Sennampatti	2.79	2.88	0.09	0.51	2.28
S <sub>33</sub>	Kulasekharam	8.63	11.46	0.69	2.48	8.29
S <sub>34</sub>	Mancode	6.93	9.74	0.50	1.97	7.27
S <sub>35</sub>	Pechiparai	7.54	11.29	0.79	4.83	5.67
S <sub>36</sub>	Mulligoor	12.23	19.08	0.91	12.09	6.08
S <sub>37</sub>	Manjoor	11.40	16.94	0.70	6.27	9.97
Minimum		1.67	0.46	0.03	0.01	0.12
Maximum		12.23	19.08	2.02	12.09	9.97

\*Bound-POM : by difference; Fine-POM & Coarse POM: by dry sieving

increasing soil labile fraction and POM have been reported in earlier studies (32). The continuous use of NPK + FYM has increased SOC content from 26 % to 52 % compared to NPK and control plots, respectively (33). Early works stated that under long term application POM increased in soil with increased input rate of organic manures application (34). The balanced fertilization of 100 % NPK with FYM contributed towards the increase in SOC, SOC stock and carbon sequestration while improving soil fertility status (35).

Constitution of POM within SOM was calculated and expressed in percentage (Table 7). Majority of soils in northwestern zone, hilly, high rainfall and Cauvery delta zone as well as in continuous cropping experiments of western zone constituted POM within SOM with a large account (> 40 %). Large account of POM within SOM might be indicative of frequent addition of partially decomposed organic particulate materials in soil happening throughout the year. Low account of POM within SOM (< 40 %) may indicate soils deprived of measurable addition organic materials regularly to soil. The irrespective of the manure or fertiliser addition, carbon content of 0.25 - 2.0 mm fraction was greater than 0.053-0.25 mm fraction of POM (36).

High account of POM constituted within SOM was 86.19 - 90.49 % in hilly zone, 76.99 - 86.85 % in high rainfall and 28.33 - 70.75 % in Cauvery delta zone, 8.78 - 77.01 % in northwestern

zone. In continuous cropping experiments high POM proportion within SOM was 75.77 % in LTFE (S<sub>16</sub>) and 69.19 % in PME (S<sub>17</sub>) of Coimbatore, in western zone. The findings of early works from the LTFE site at TNAU Coimbatore also clearly demonstrated that balanced fertilization combined with the application of farmyard manure (FYM) at 10 t ha<sup>-1</sup> significantly enhanced soil organic carbon and nutrient status over time (37). This long-term approach has proven to be sustainable, contributing to improved soil health and fertility under continuous cropping systems.

In Nanguneri series, found that SOC stock was highest under forest land use while it was lowest under agriculture land use (38). The build-up of POM in soil increased at a faster rate in all perennial crops than in annual row crop rotation (39). On further turn over labile and recalcitrant C fractions of POM were sequestered in soil aggregates by chemical bonds that resist decomposition. Hence, POM could be considered as a sensitive indicator of soil quality than SOC alone (40, 41).

Fractions of POM within SOM indicated that the coarse POM constituted high portion (60.88 %) in Mancode soil (S<sub>34</sub>) of high rainfall zone, fine POM constituted high portion (57.34 %) in Mulligoor soil (S<sub>36</sub>) of hilly zone and bound POM constituted high portion (21.88 %) in Jallipatti soil (S<sub>15</sub>) of western zone. Report of early works indicated that contribution of POM to Soil organic

**Table 7.** Apportioning of particulate organic matter within soil organic matter

Soil sample No.	Name of sampled location	POM within SOM (%)	Fractions of POM		
			Bound POM within SOM (%)	Fine POM within SOM (%)	Coarse POM within SOM (%)
S <sub>1</sub>	Cheyar	26.20	1.48	1.28	23.44
S <sub>2</sub>	Vadathandalam	48.63	1.08	12.08	35.47
S <sub>3</sub>	Mazhaiyur	62.05	1.04	22.52	38.50
S <sub>4</sub>	Aliyur	51.43	8.24	24.41	18.78
S <sub>5</sub>	Manampathi	46.36	2.41	4.21	39.74
S <sub>6</sub>	Manampathi Kandigai	7.67	0.52	0.78	6.37
S <sub>7</sub>	Mallur	31.29	0.79	9.04	21.45
S <sub>8</sub>	Pasuvanathampatty	8.78	0.45	0.15	8.18
S <sub>9</sub>	Uthangakarai	23.29	0.53	4.81	17.95
S <sub>10</sub>	Mukanurpatti G	26.87	5.55	7.73	13.68
S <sub>11</sub>	Morappur	77.01	1.47	22.93	52.61
S <sub>12</sub>	Anthiyur	32.89	0.38	1.42	31.09
S <sub>13</sub>	Kuthampalayam	6.25	2.08	2.33	2.70
S <sub>14</sub>	Sinjuvadi	3.80	0.38	2.66	0.76
S <sub>15</sub>	Jallipatti	36.47	21.88	5.56	9.03
S <sub>16</sub>	TNAU-LTFE	75.77	3.90	26.65	45.23
S <sub>17</sub>	TNAU-PME	69.19	19.15	31.47	18.58
S <sub>18</sub>	Chinthalavadi	40.58	6.52	16.89	17.16
S <sub>19</sub>	Lalapettai	40.57	1.51	5.86	33.20
S <sub>20</sub>	Karuppathur	56.13	4.84	22.34	28.95
S <sub>21</sub>	Thirumanur	28.33	0.83	2.17	25.33
S <sub>22</sub>	Pattukudi	70.75	17.00	10.73	43.03
S <sub>23</sub>	Thiruvaiyaru	69.59	17.07	25.36	27.16
S <sub>24</sub>	Kuruvasi	53.91	2.19	35.42	16.30
S <sub>25</sub>	Tulukkapatti	18.66	1.14	2.35	15.17
S <sub>26</sub>	Avudaiyapuram	23.55	0.97	14.47	8.10
S <sub>27</sub>	Vadipatti	74.43	3.71	31.36	39.37
S <sub>28</sub>	Andipatti	10.85	1.41	2.83	6.60
S <sub>29</sub>	Venkateswarapuram	8.65	0.90	2.70	5.04
S <sub>30</sub>	Kasilingapuram	15.83	1.04	12.13	2.65
S <sub>31</sub>	Lakshimpuram	59.31	5.20	45.78	8.32
S <sub>32</sub>	Sennampatti	59.88	1.87	10.60	47.40
S <sub>33</sub>	Kulasekharan	76.99	4.64	16.66	55.69
S <sub>34</sub>	Mancode	81.56	4.19	16.50	60.88
S <sub>35</sub>	Pechiparai	86.85	6.08	37.16	43.62
S <sub>36</sub>	Mulligoor	90.49	4.32	57.34	28.84
S <sub>37</sub>	Manjoor	86.19	3.56	31.90	50.73
Minimum		3.80	0.38	0.15	0.76
Maximum		90.49	21.88	57.34	60.88

\*POM – Particulate organic matter; SOM – Soil organic matter

matter was 16–39% and the variations occurred depended on agro-ecosystems and soil management practices (42). The more C ( $18.6 \text{ g kg}^{-1}$ ) was distributed in coarse POM ( $> 0.25 \text{ mm}$ ) while less C ( $4.5 \text{ g kg}^{-1}$ ) was distributed in fine POM fraction ( $0.25 - 2 \text{ mm}$ ) (43). Maximum SOC stock was registered in macro-sized fraction ( $47.0 \text{ mg ha}^{-1}$ ), microsized fraction ( $45.9 \text{ mg ha}^{-1}$ ) and silt+clay sized fraction ( $52.4 \text{ mg ha}^{-1}$ ) in Mayamankurichi series under forest land use (38).

Within POM, the physical fractions POM varied in composition. The large size coarse fraction ( $0.5\text{-}2.0 \text{ mm}$ ) constituted between 14.04-94.52 %, small size fractions viz., fine POM ( $< 0.5 \text{ mm}$ -floating) constituted between 1.69 - 77.19 % and bound POM ( $< 0.5 \text{ mm}$  - particle bound) constituted between 1.15 - 60.0 % among all soils of Tamil Nadu (Fig. 5). The dominance of coarse fraction within POM ( $> 60 \%$ ) was highly accounted in majority samples of north-eastern zone ( $S_1 - S_6$ ) ranging between 36.51 and 89.47, north-western zone ( $S_7 - S_{11}$ ) ranging between 50.92 and 93.22 and in high rainfall zone ( $S_{33} - S_{35}$ ) ranging between 50.22 and 74.64. A high proportion of coarse POM may indicate persistence of large particles in soil because of insufficient moisture and biological activity for further decomposition.

#### Soil properties and organic matter status of districts of Tamil Nadu

Soil samples were collected from 16 districts covering all agro-climatic zones of Tamil Nadu. There were considerable variations among districts in terms of soil properties. Soils collected were in acid range at Udagamandalam and Kanyakumari districts, near calcareous in Coimbatore and Kanchipuram districts while other soils were near neutral. All soil samples of districts were non-saline. CEC of the soils were very high in Udagamandalam and

Virudhunagar districts. Except in Udagamandalam and Kanyakumari districts, other districts contained substantial  $\text{CaCO}_3$  content (Table 8).

Soils of Udagamandalam district contained the highest SOC, POM and fractions of POM, followed by Kanyakumari district (Fig. 6 and Fig. 7). In other districts organic matter content ranged from low to moderate levels.

In certain districts, collected soil samples contained low POM status, which might be related to the prevailed hot weather, lack of adequate rainfall, mono cropping and poor soil management strategies followed. Reduced POM levels in soils would be related to transient nature of POM fraction, timing of crop residue inputs, fertilizer application and rate of decomposition of SOM (44, 45).

#### Relationships between soil properties and particulate organic matter

Simple correlation analysis performed between soil properties and organic matter content of soils brought out vital association between certain parameters. The strength of relationship was confirmed by coefficient of determination expressed in percentage in parenthesis (Table 9).

For SOC, a negative relationship with soil pH (25.5%), coarse sand (21.2%), fine sand (27.0%) and a positive relationship with CEC (16.8 %) and clay (25.4 %) was determined. For POM, a negative relationship with soil pH (45.9 %),  $\text{CaCO}_3$  (36.2 %), fine sand (13.7 %) and a positive relationship with SOC (52.8 %) was determined. For bound POM, a negative relationship with soil  $\text{CaCO}_3$  (17.4 %) and a positive relationship with POM (23.8 %) was observed.

For fine POM, a negative relationship with soil pH (33.2 %),  $\text{CaCO}_3$  (28.5 %), fine sand (12.2 %) and a positive relationship with

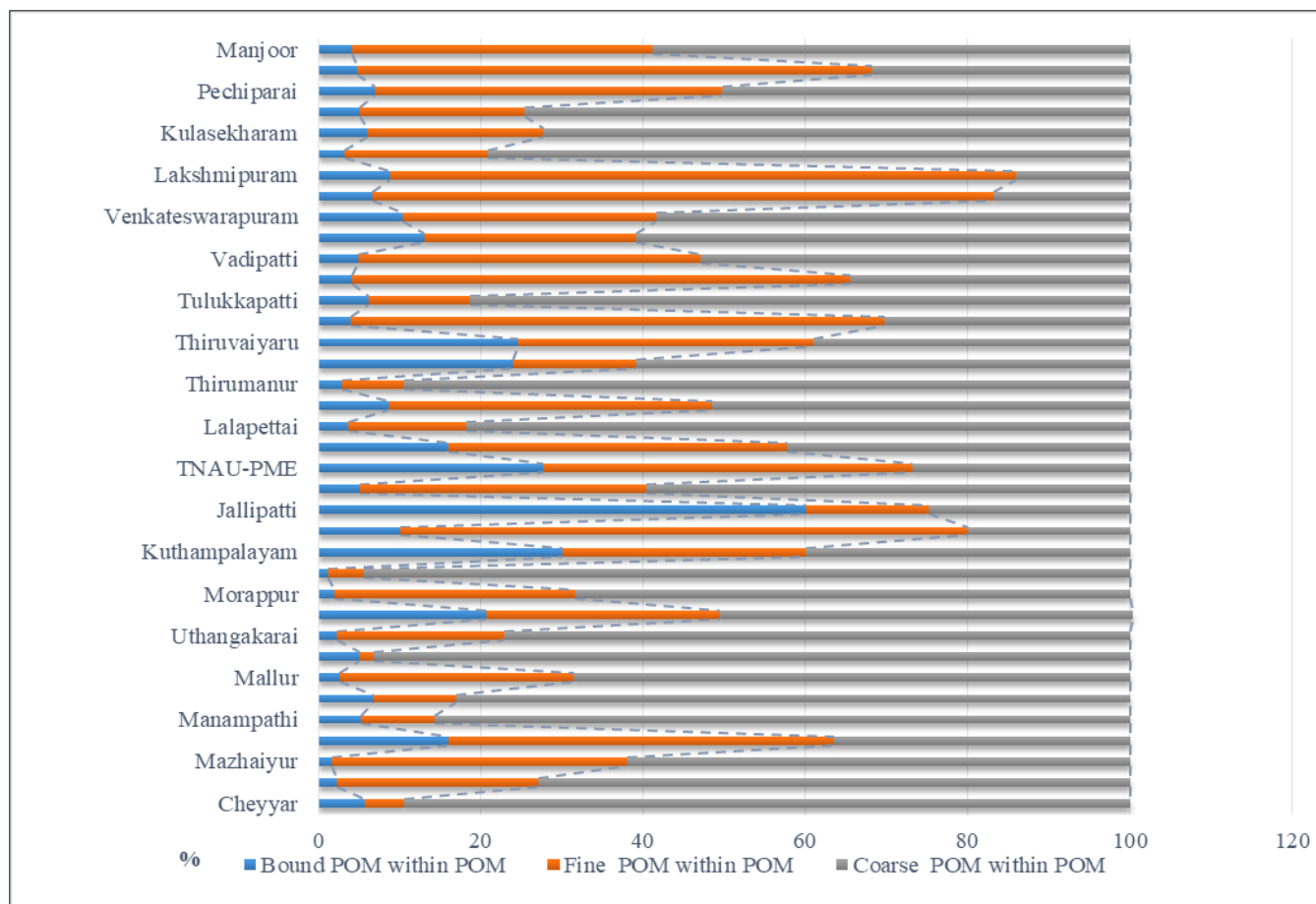


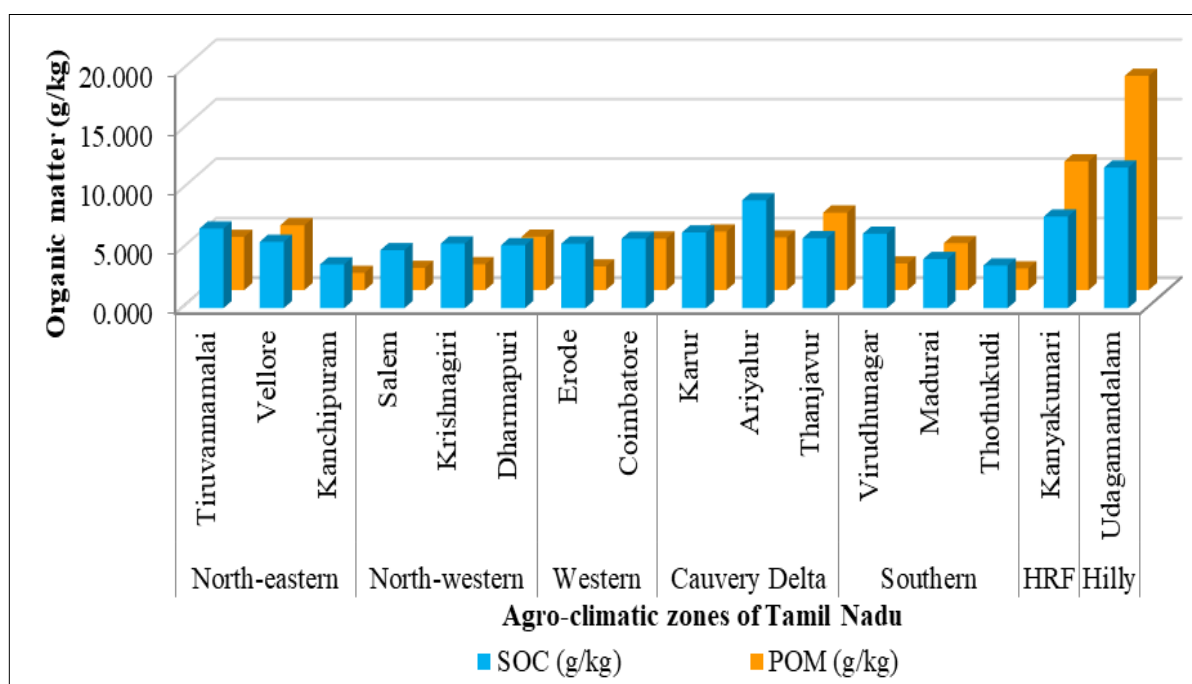
Fig. 5. Apportioning of fractions of particulate organic matter within POM.

**Table 8.** Chemical characteristics and organic matter status of soils in sampled districts of Tamil Nadu

Chemical characteristics						
S. No.	Name of districts	pH (1:2.5 ratio)	EC (dS m <sup>-1</sup> )	CEC cmol (p <sup>+</sup> ) kg <sup>-1</sup> soil	CaCO <sub>3</sub> (%)	
1	Tiruvannamalai	7.22	0.22	9.76	7.84	
2	Vellore	6.76	0.44	9.15	3.08	
3	Kanchipuram	8.10	0.54	9.59	8.25	
4	Salem	7.83	0.12	9.10	6.13	
5	Krishnagiri	7.88	0.05	7.40	6.97	
6	Dharmapuri	7.32	0.60	11.10	5.62	
7	Erode	7.88	0.64	11.13	6.59	
8	Coimbatore	8.19	0.12	11.86	6.82	
9	Karur	7.55	0.46	10.48	5.22	
10	Ariyalur	7.68	1.01	14.38	8.56	
11	Thanjavur	7.47	0.96	5.25	4.06	
12	Virudhunagar	8.19	0.09	17.25	9.44	
13	Madurai	7.00	0.01	7.25	3.09	
14	Thothukudi	7.12	0.15	10.07	6.03	
15	Kanyakumari	5.06	0.25	8.20	0.43	
16	Udagamandalam	5.05	0.08	18.34	0.55	

(2) Organic matter status						
S. No.	Name of districts	SOC (g kg <sup>-1</sup> )	POM (g kg <sup>-1</sup> )	Fractions of POM (g kg <sup>-1</sup> )		
				Bound POM	Fine POM	Coarse POM
1	Tiruvannamalai	6.690	4.470	0.145	0.845	3.480
2	Vellore	5.575	5.455	0.445	2.255	2.755
3	Kanchipuram	3.675	1.450	0.080	0.135	1.235
4	Salem	4.870	1.870	0.055	0.460	1.355
5	Krishnagiri	5.430	2.180	0.050	0.450	1.680
6	Dharmapuri	5.290	4.495	0.340	1.325	2.835
7	Erode	5.425	1.990	0.105	0.170	1.750
8	Coimbatore	5.840	4.328	0.785	1.710	1.833
9	Karur	6.360	4.920	0.453	1.553	2.913
10	Ariyalur	9.070	4.430	0.130	0.340	3.960
11	Thanjavur	5.880	6.517	1.183	2.480	2.853
12	Virudhunagar	6.260	2.240	0.115	0.815	1.310
13	Madurai	4.125	3.945	0.215	1.625	2.105
14	Thothukudi	3.590	1.828	0.113	0.925	0.790
15	Kanyakumari	7.700	10.830	0.660	3.093	7.077
16	Udagamandalam	11.815	18.010	0.805	9.180	8.025

**Fig. 6.** Status of POM in sampled districts of Tamil Nadu.

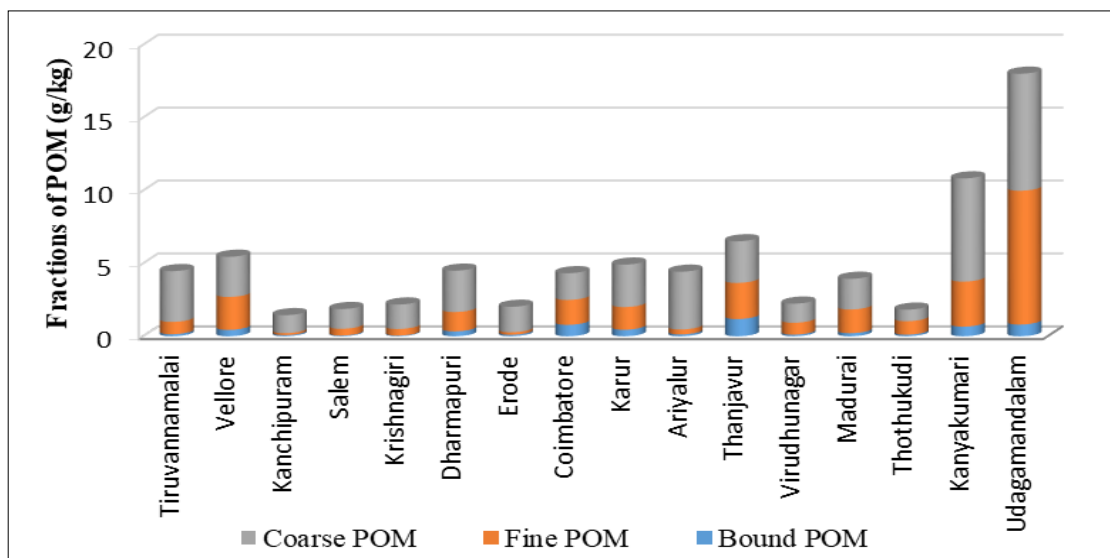


Fig. 7. Bound, fine and coarse fractions within POM in soils of selected districts of Tamil Nadu.

Table 9. Correlation analysis between soil properties and organic matter status

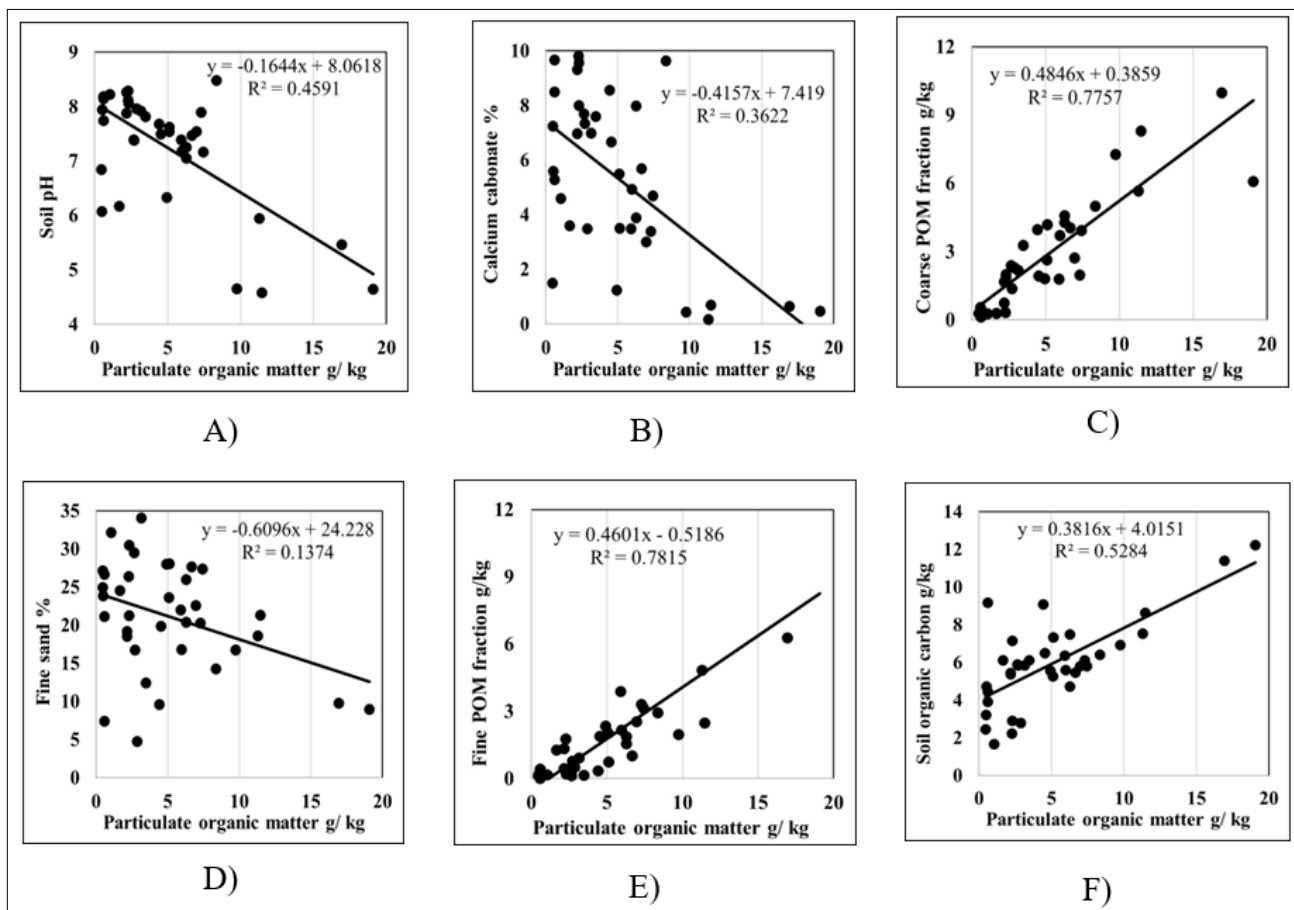
Dominant soil properties	Components of soil organic matter				
	SOC	POM	Bound- POM fraction	Fine-POM fraction	Coarse-POM fraction
Simple correlation (r)					
(1) with basic soil properties					
pH	-0.505**	-0.678	-0.204 <sup>NS</sup>	-0.576**	-0.644**
EC	0.016 <sup>NS</sup>	-0.020 <sup>NS</sup>	0.219 <sup>NS</sup>	-0.107 <sup>NS</sup>	0.022 <sup>NS</sup>
CEC	0.410**	0.204 <sup>NS</sup>	-0.107 <sup>NS</sup>	0.178 <sup>NS</sup>	0.224 <sup>NS</sup>
CaCO <sub>3</sub>	-0.249 <sup>NS</sup>	-0.602**	-0.417*	-0.534**	-0.504**
SOC		0.727**	0.221 <sup>NS</sup>	0.642**	0.669**
POM			0.488**	0.884**	0.881**
Coefficient of determination (r <sup>2</sup> )					
pH	0.255	0.459	0.042	0.332	0.415
EC	-	-	0.048	0.011	-
CEC	0.168	0.042	0.011	0.032	0.050
CaCO <sub>3</sub>	0.062	0.362	0.174	0.285	0.254
SOC		0.528	0.049	0.412	0.447
POM			0.238	0.781	0.776
(2) with soil particle size groups					
Dominant Soil Properties	Components of soil organic matter				
	SOC	POM	Bound- POM fraction	Fine-POM fraction	Coarse-POM fraction
Simple correlation (r)					
Coarse sand	-0.460**	-0.271 <sup>NS</sup>	0.059 <sup>NS</sup>	-0.255 <sup>NS</sup>	-0.264 <sup>NS</sup>
Fine sand	-0.519**	-0.371*	0.002 <sup>NS</sup>	-0.349*	-0.344*
Silt	0.264 <sup>NS</sup>	0.297 <sup>NS</sup>	0.163 <sup>NS</sup>	0.144 <sup>NS</sup>	0.371 <sup>NS</sup>
Clay	0.504**	0.277 <sup>NS</sup>	-0.099 <sup>NS</sup>	0.310 <sup>NS</sup>	0.231 <sup>NS</sup>
Coefficient of determination (r <sup>2</sup> )					
Coarse sand	0.212	-	-	-	-
Fine sand	0.270	0.137	-	0.122	0.118
Silt	-	-	-	-	-
Clay	0.254	-	-	-	-

r value: Not significant (< 0.325); Significant at 5% (> 0.325) and at 1% (> 0.418) levels

SOC (41.2%), POM (78.1%) was determined. For coarse POM, a negative relationship with soil pH (41.5%), CaCO<sub>3</sub> (25.4%), fine sand (11.8%) and a positive relationship with SOC (44.7%), POM (77.6%) was determined.

Correlation analysis revealed a strong positive relationship between SOC and POM (Fig. 8). Both were mutually positively related which could be the indication that significant quantity of C was contributed by POM to SOC, because SOC represents a particle fraction of soil < 0.5 mm, while POM accounted for a size fraction of 0.053 - 2.0 mm. Similar findings have been reported by previous works (46).

Both SOC and POM inversely correlated with soil pH, which may be the indication that accumulation of organic matter in acidic soils occurred largely as end products of decomposition and depletion of organic matter happened due to microbial oxidation in soils with alkaline pH. In other words, indirectly it could be attributed to microbial activity. Under acidic soil conditions fungi and actinomycetes would be more active, but they are slow decomposers of organic matter. Soils with neutral and alkaline pH supported abundant bacterial communities, which are fast and efficient decomposers of organic matter. These results corroborate to the findings of early works who have reported that both the relative abundance and diversity of bacteria were positively related to pH (47).



**Fig. 8.** Correlation for POM with soil properties.

Further, the diversity of bacterial communities nearly doubled between pH 4 and 8 and therefore quickly decompose soil organic matter. On the contrary the relative abundance of fungi was unaffected by pH, because fungi generally exhibit a wider range of pH for optimal growth.

Positive relationship for SOC and POM with clay may be attributed to the physical binding and chemical adsorption of fine organic fraction and C compounds on charged surfaces clay, which increased with increase in the content of clay. Conversely better aeration and lack of binding ability associated with sand fraction showed an inverse relationship with SOC and POM. In similar studies reported positive relationships with clay, clay + silt and a negative relationship for quartz fraction for soil organic matter (42). The retention of more SOC occurred in soil aggregates measuring > 0.25 mm and after 25 years of fertilization most of SOC was total N were sequestered in macroaggregates of 0.25 - 2 mm (48).

## Conclusion

Agro-ecosystems, which cover over 40 % of the world's land surface, are increasingly vital for promoting sustainable agriculture and long-term carbon sequestration. Among soil organic components, POM plays a critical role in the build-up of SOC and the enhancement of fertility-related properties. This study revealed significant spatial variation in POM abundance across the agro-climatic zones of Tamil Nadu. Specifically, soil in the hilly and high-altitude zone ( $S_{36}$  -  $S_{37}$ ), high rainfall zone ( $S_{33}$  -  $S_{35}$ ) and Cauvery delta zone ( $S_{18}$  -  $S_{24}$ ) exhibited consistently higher POM levels, attributed to cool weather, frequent rainfall, humid climate and prolonged soil moisture conditions that favor organic matter accumulation. Additionally,

soils from the LTFE and PME plots at TNAU, Coimbatore, located in the western zone, also recorded elevated POM due to sustained organic amendments and continuous cropping. These findings underscore the importance of regular application of organic manures and crop residues, especially in agro-ecosystems where climatic limitations hinder natural POM build-up. Targeted organic input strategies are therefore essential for maintaining soil health and supporting resilient agro-ecosystems under varying climatic conditions.

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## Authors' contributions

AK designed the work. EN performed the laboratory work and data analysis. AK assisted in data analysis. EN wrote the original draft while AK reviewed and edited the original draft of the manuscript. All the authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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